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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference TS 6320 PCT	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/EP 02/14864	International filing date *(day/month/year)* 31.12.2002	Priority date *(day/month/year)* 31.12.2001
International Patent Classification (IPC) or both national classification and IPC B01D45/16		
Applicant SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 14 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand 15.07.2003	Date of completion of this report 19.03.2004
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer Bogaerts, M Telephone No. +31 70 340-2335

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP 02/14864

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1, 9-20	as originally filed
2-8, 8a	received on 24.12.2003 with letter of 24.12.2003

Claims, Numbers

1-18	received on 24.12.2003 with letter of 24.12.2003

Drawings, Sheets

1/4-4/4	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:
   - ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-18
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-18
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-18
	No:	Claims	

2. Citations and explanations

   see separate sheet

Ad V

The subject-matter of independent claims 1 and 17 differs from D1 in that a plurality of fluid injection conduits are distributed at regular circumferential intervals around a tubular section of the secondary separation vessel, whereas in D1 a single fluid injection conduit is provided.

The technical effects achieved by this difference are:
- stabilization of the vortex in the secondary separation vessel.
- allows continuous operation of the secondary separator vessel.

The proposed solution (see differences) is not obvious for a skilled person.

The application meets the requirements of Article 33 (2), (3) and (4) PCT.

ALL REPLACED BY ART 34 AMDT

via a gas outlet conduit near the upper end of the LTX vessel.

US patent 4,208,196 discloses an LTX vessel into which well effluents are injected without prior expansion in a choke. The known LTX vessel is provided with a vertically oriented tubular inlet section into which the well effluents are injected tangentially to enhance segregation of liquefied and/or solidified components from the gaseous components by centrifugal forces. The tubular inlet section is capped and provided with a grating structure at its lower end to inhibit extension of the swirl induced in the inlet section into the liquid collecting region at the bottom of the LTX tank. The tubular inlet section is located inside a cylindrical and horizontal separation tank in which water and oil are collected and separated from each other by gravity segregation, and are subsequently tapped off via separate water and oil discharge tubes near the bottom of the tank. The gaseous components are induced to flow through the grating down from the tubular inlet section into the separation tank and removed from the top of the separation tank at a significant distance from the inlet section.

International patent application PCT/NL00/00382 discloses a separation vessel for separating heavy, such as liquid or solid, components from a gaseous mixture in which vessel countercurrent inner and outer swirls are induced by countercurrent swirl imparting vanes arranged near the centre and outer periphery of the vessel.
A disadvantage of this known device is that the swirl imparting vanes are prone to fouling.

International patent application PCT/EP98/04178 discloses a supersonic cyclonic inertia separator in

which the produced well effluents are drastically cooled down by adiabatic expansion as a result of their acceleration to a supersonic velocity in a supersonic nozzle. In the supersonic nozzle a swirl is created to segregate the thus condensed and/or solidified heavy components from the lighter gaseous components. The gaseous condensables depleted components are discharged from the separator through a central primary gas outlet conduit whereas the condensables enriched components are discharged from the separator through one or more secondary outlet conduits which extend away from a central axis of the nozzle.

It has been found that the secondary condensables enriched fluid outlet of a supersonic cyclonic inertia separator may be connected to an LTX vessel, but that the high velocity of the injected liquefied and/or solidified condensables enriched fluid mixture resulted in a reduced gravity separation efficiency of the LTX vessel.

It is an object of the present invention to provide a hybrid multistage fluid separation assembly in which an LTX type separation vessel is connected to liquefied and/or solidified condensables enriched fluid outlet of one or more gas cooling devices such as supersonic and/or subsonic cyclonic inertia separators such that a synergetic effect is obtained between the performance of the gas cooling device, such as a cyclonic inertia separator, and the LTX separation vessel.

It is a further object to provide a hybrid multistage fluid separation assembly, which is more compact than a combination of a gas cooling device, such as a cyclonic inertia separator, and a conventional LTX vessel.

It is yet a further object to provide a hybrid multistage fluid separation assembly in which a plurality

of gas cooling devices, such as cyclonic inertia separators, can be connected to a single compact LTX vessel by relatively short liquefied and/or condensables enriched fluid outlet conduits such that the risk of solids, wax and/or hydrate deposition in these secondary outlet conduits is minimized.

SUMMARY OF THE INVENTION

In accordance with the invention there is provided a multistage fluid separation assembly comprising:

one or more primary gas cooling devices which each have a liquefied and/or solidified condensables enriched fluid outlet; and

a secondary fluid separation vessel having a tubular section of which a central axis has a substantially vertical or tilted orientation, which vessel is connected to said condensables enriched fluid outlet of at least one of said gas cooling devices, wherein during normal operation of the vessel the condensables enriched fluid is induced to swirl around the central axis of the tubular section of the vessel such that a tertiary stream of liquified and/or solidified condensables is induced by gravity and centrifugal forces to swirl in downward direction alongside the inner surface of the tubular section of the vessel into a liquid collecting tank at or near the bottom of the vessel for collecting a tertiary mixture of liquified and/or solidified condensables, which tank is provided with one or more heaters for heating the tertiary mixture to reduce the amount of solidified condensables and with one or more outlets for discharging the tertiary mixture from the tank.

It is preferred that the tubular section of the secondary separation vessel is equipped with a tertiary gas outlet conduit having an inlet which is located at or

near the central axis of the tubular section and which tertiary gas outlet extends through an upper end of the tubular section of the secondary separation vessel.

Suitably, the secondary separation vessel has a dome- or disk-shaped top, which is mounted on top of the tubular section and the tertiary gas outlet conduit is arranged substantially co-axial to the central axis of the tubular section and passes through the centre of the top.

Preferably, the liquefied and/or solidified condensables enriched fluid outlet of at least one primary cooling device, such as a cyclonic fluid separator, is connected to a secondary fluid injection conduit which injects the condensables enriched fluid in an at least partially tangential direction into the tubular section of the secondary separation vessel.

It is also preferred that the central axis of the tubular section of the secondary separation vessel has a substantially vertical orientation and that a plurality of secondary fluid injection conduits of a plurality of primary gas cooling devices are connected at regular circumferential intervals to the tubular section of the secondary separation vessel, which conduits inject in use liquefied and/or solidified condensables enriched fluid in an at least partially tangential and partially downward direction into the interior of the secondary separation vessel.

Suitably, the liquid collecting tank is formed by a cup-shaped tubular lower portion of the second stage separation vessel which is substantially co-axial to the central axis and has a similar or larger internal width than the upper portion of the vessel and a vortex breaker is arranged in the interior of the secondary separation

vessel between the lower end of the tubular section and the liquid collecting tank.

The assembly may be provided with one or more ultrasonic vibration transducers for imposing ultrasonic vibrations at a frequency between 20 and 200 KHz on one or more components of the assembly, such as the secondary fluid injection tubes and the vortex breaker, to inhibit deposition of solidified condensables, such as ice, wax and/or hydrates, within the assembly.

The liquid collecting tank may be provided with a grid of heating tubes, which are designed to heat the liquid and solid fluid mixture in the tank to a temperature of at least 15 degrees Celsius.

One or more primary gas cooling devices may comprise cyclonic inertia separators which comprise an expansion nozzle in which the fluid mixture is cooled to a temperature lower than 0 degrees Celsius by a substantially isentropic expansion and in which one or more swirl imparting vanes induce the fluid to swirl into a diverging outlet section which is equipped with a central primary condensables depleted fluid outlet conduit and an outer secondary condensables enriched fluid outlet conduit.

Suitably each primary gas cooling device, such as a cyclonic inertia separator, comprises an expansion nozzle, which is designed to accelerate the fluid mixture within the nozzle to a supersonic speed, thereby cooling in use the temperature of the fluid passing through the nozzle to a temperature lower than -20 degrees Celsius.

The fluid separation assembly according to the invention may comprise a plurality of primary cyclonic inertia separators of which the expansion nozzles are substantially parallel and equidistant to the central

axis of the tubular section of the secondary separation vessel and of which the secondary condensables enriched fluid outlets are connected to secondary fluid injection conduits which intersect the wall of the tubular section of the secondary separation vessel at regular circumferential intervals and in an at least partially tangential direction, and which secondary fluid injection conduits each have a length less than 4 metres.

The gas cooling devices may comprise chokes known as Joule-Thompson valves in which the gas is accelerated and cooled by expansion such that a liquefied and/or solidified condensables enriched fluid is generated, which is subsequently fed into the secondary fluid separation vessel.

The invention also relates to a method of separating condensable components from a fluid mixture in a multistage fluid separation assembly, which method comprises:

injecting the fluid mixture into one or more primary gas cooling devices in which the fluid mixture is expanded and cooled and condensable components are liquefied and/or solidified and optionally separated from the gaseous components by centrifugal force, and in which a stream of condensables enriched fluid components is fed into a secondary fluid outlet; and

injecting the stream of condensables enriched fluid components into a secondary fluid separation vessel having a tubular section of which a central axis has a substantially vertical or tilted orientation and in which the condensables enriched fluid stream is induced to swirl around the central axis of the tubular section of the vessel such that a tertiary mixture of liquified and/or solidified condensables is induced by gravity and

centrifugal forces to swirl in downward direction alongside the inner surface of the tubular section of the vessel into a liquid collecting tank at or near the bottom of the vessel, in which tank the tertiary mixture of liquified and/or solidified condensables is collected and heated to reduce the amount of solidified condensables and from which tank liquid and/or solidified components are discharged through one or more outlets.

DESCRIPTION OF SUITABLE EMBODIMENTS

Suitable embodiments of a multistage fluid separation assembly according to the present invention will be described in more detail with reference to the accompanying drawings wherein:

Fig. 1 is a schematic vertical split sectional view of a first suitable embodiment of a multistage fluid separation assembly according to the invention wherein four primary cyclonic inertia separators discharge a condensables enriched fluid mixture into a vertically oriented tubular secondary fluid separation vessel;

Fig.2 is a top view of the multistage fluid separation assembly of Fig.1;

Fig.3 is a schematic vertical split sectional view of another suitable embodiment of a multistage fluid separation assembly according to the invention wherein two primary cyclonic inertia separators discharge a condensables enriched fluid mixture into a horizontally oriented secondary fluid separation vessel;

Fig.4 is a horizontal cross-sectional view of the multistage fluid separation assembly of Fig.3, taken across the primary cyclonic inertia separators and seen from above;

Fig. 5 is a schematic horizontal sectional view of a simplified multistage fluid separation assembly of which

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C L A I M S

1. A multistage fluid separation assembly comprising:
one or more primary gas cooling devices which each have a liquefied and/or solidified condensables enriched fluid outlet; and
a secondary fluid separation vessel having a tubular section of which a central axis has a substantially vertical or tilted orientation, which vessel is connected to said condensables enriched fluid outlet of at least one of said gas cooling devices, wherein during normal operation of the vessel the condensables enriched fluid is induced to swirl around the central axis of the tubular section of the vessel such that a tertiary stream of liquified and/or solidified condensables is induced by gravity and centrifugal forces to swirl in downward direction alongside the inner surface of the tubular section of the vessel into a liquid collecting tank at or near the bottom of the vessel for collecting a tertiary mixture of liquified and/or solidified condensables, which tank is provided with one or more heaters for heating the tertiary mixture to reduce the amount of solidified condensables and with one or more outlets for discharging the tertiary mixture from the tank.
2. The fluid separation assembly of claim 1, wherein the liquid collecting tank comprises an upper liquid outlet for low density liquid components and a lower liquid outlet for high density liquid components.
3. The fluid separation assembly of claim 1 or 2, wherein the tubular section of the secondary separation vessel is equipped with a tertiary gas outlet conduit

having an inlet which is located at or near the central axis of the tubular section.

4. The fluid separation assembly of claim 3, wherein the secondary separation vessel has a dome or disk shaped top which is mounted on top of the tubular section and the tertiary gas outlet conduit is arranged substantially co-axial to the central axis of the tubular section and passes through said top.

5. The fluid separation assembly of claim 1, wherein the liquefied and/or solidified condensables enriched fluid outlet of at least one primary gas cooling device is connected to a secondary fluid injection conduit which injects in use the condensables enriched fluid in an at least partially tangential direction into the tubular section of the secondary separation vessel.

6. The fluid separation assembly of claim 5, wherein the central axis of the tubular section of the secondary separation vessel has a substantially vertical orientation and a plurality of secondary fluid injection conduits of a plurality of primary gas cooling devices are connected at regular circumferential intervals to the tubular section of the secondary separation vessel, which conduits inject in use condensables enriched fluid in an at least partially tangential and partially downward direction into the interior of the secondary separation vessel.

7. The fluid separation assembly of claim 1, wherein the liquid collecting tank is formed by a cup-shaped tubular lower portion of the second stage separation vessel which is substantially co-axial to the central axis and has a larger internal width than the upper portion of the vessel.

8. The fluid separation assembly of claim 1, wherein a vortex breaker is arranged in the interior of the secondary separation vessel between the lower end of the tubular section and the liquid collecting tank.

9. The fluid separation assembly of claim 1, wherein the assembly is provided with one or more ultrasonic vibration transducers for imposing ultrasonic vibrations on one or components of the assembly to inhibit deposition of solidified condensables, such as ice, wax and/or hydrates, within the assembly.

10. The fluid separation assembly of claims 5, 8 and 9, wherein at least the secondary fluid injection conduits and the vortex breaker are equipped with ultrasonic vibration transducers.

11. The fluid separation assembly of claim 9 or 10, wherein the ultrasonic vibration transducers are designed to vibrate in use one or more components of the assembly at a frequency between 20 and 200 KHz.

12. The fluid separation assembly of claim 1, wherein the liquid collecting tank is provided with a grid of heating tubes which are designed to heat the liquid and solid fluid mixture in the tank to a temperature of at least 15 degrees Celsius.

13. The fluid separation assembly of any preceding claim, wherein each gas cooling device comprises a primary cyclonic inertia separator comprising an expansion nozzle in which the fluid mixture is cooled to a temperature lower than 0 degrees Celsius by a substantially isentropic expansion and in which one or more swirl imparting vanes induce the fluid to swirl into a diverging outlet section which is equipped with a central primary condensables depleted fluid outlet

conduit and an outer secondary condensables enriched fluid outlet conduit.

14. The fluid separation assembly of claim 13, wherein each primary cyclonic inertia separator comprises an expansion nozzle which is designed to accelerate the fluid mixture within the nozzle to a supersonic speed, thereby cooling in use the temperature of the fluid passing through the nozzle to a temperature lower than -20 degrees Celsius.

15. The fluid separation assembly of claim 13 or 14, comprising a plurality of primary cyclonic inertia separators of which the expansion nozzles are substantially parallel and equidistant to the central axis of the tubular section of the secondary separation vessel and of which the secondary condensables enriched fluid outlets are connected to secondary fluid injection conduits which intersect the wall of the tubular section of the secondary separation vessel at regular circumferential intervals and in an at least partially tangential direction, and which secondary fluid injection conduits each have a length less than 4 metres.

16. The fluid separation assembly of claim 1, wherein the gas cooling devices comprise chokes such as Joule Thompson valves.

17. A method of separating condensable components from a fluid mixture in a multistage fluid separation assembly, the method comprising:

injecting the fluid mixture into one or more primary gas cooling devices in which the fluid mixture is expanded and cooled and condensable components are liquefied and/or solidified and optionally separated from the gaseous components by centrifugal force, and in

which a stream of condensables enriched fluid components is fed into a secondary fluid outlet; and

injecting the stream of condensables enriched fluid components into a secondary fluid separation vessel having a tubular section of which a central axis has a substantially vertical or tilted orientation and in which the condensables enriched fluid stream is induced to swirl around the central axis of the tubular section of the vessel such that a tertiary mixture of liquified and/or solidified condensables is induced by gravity and centrifugal forces to swirl in downward direction alongside the inner surface of the tubular section of the vessel into a liquid collecting tank at or near the bottom of the vessel, in which tank the tertiary mixture of liquified and/or solidified condensables is collected and heated to reduce the amount of solidified condensables and from which tank liquid and/or solidified components are discharged through one or more outlets.

18. The method of claim 17, wherein the fluid mixture is a natural gas stream which is cooled in gas cooling devices comprising one or more primary cyclonic inertia separators to a temperature below 0 degrees Celsius thereby condensing and/or solidifying aqueous and hydrocarbon condensates and gas hydrates and the tertiary fluid mixture comprises water, ice, hydrocarbon condensates and gas hydrates and is heated in the tertiary fluid collecting tank to a temperature above 15 degrees Celsius to reduce the amount of gas hydrates, and from which tank low density hydrocarbon condensates are discharged through an upper liquid

outlet and high density aqueous components are discharged through a lower liquid outlet.